

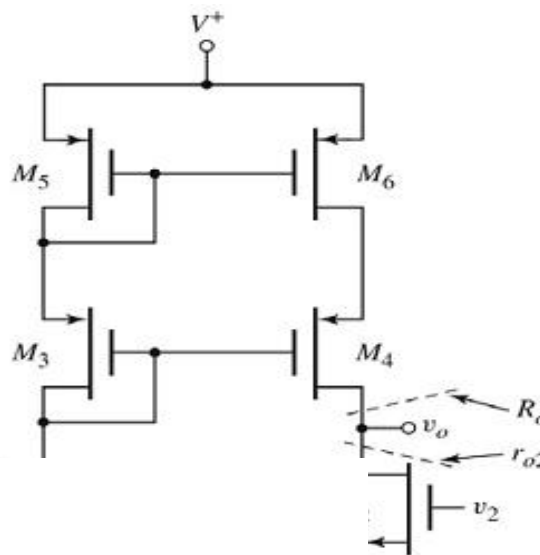
**Question:**

For a MOSFET differential amplifier with **cascode active load** shown in **Figure 1** the transistor parameters are  $g_m = 1.2 \text{ mA/V}$  for all transistors;  $K_n = 0.4 \text{ mA/V}^2$  and  $\lambda_n = 0.020 \text{ V}^{-1}$  for N-MOSFET transistors; and  $\lambda_p = 0.015 \text{ V}^{-1}$  for P-MOSFET transistors.

**Find** bias current ( $I_Q$ ) and **calculate** one-sided differential mode gain ( $A_d$ ) with output taken at  $v_o$ . **Show clearly** all formula used and calculations done as marks are given according to this.

[10 marks]

**Answer:**



$$g_m = 2 \sqrt{K_{n2} \times I_{DQ}} = 2 \sqrt{K_{n2} \times (I_Q/2)}$$

$$I_Q = [g_m / 2]^2 \times [2 / K_{n2}] = [g_m]^2 / [2 K_{n2}] = [1.2\text{m}]^2 / [2 \times 0.4\text{m}] = 1.8 \text{ mA} \quad [1]$$

$$I_{DQ} = I_Q / 2 = 0.9 \text{ mA} \quad [1]$$

$$r_{o2} = 1 / (\lambda_n I_{DQ}) = 1 / (0.020 \times 0.9\text{m}) = 55.556 \text{ k}\Omega \quad [1]$$

$$r_{o4} = r_{o6} = 1 / (\lambda_p I_{DQ}) = 1 / (0.015 \times 0.9\text{m}) = 74.074 \text{ k}\Omega \quad [1]$$

$$R_o = g_m r_{o4} r_{o6} = (1.2\text{m})(74.074\text{k})(74.074\text{k}) = 6.584 \text{ M}\Omega \quad [1]$$

$$A_d = g_m (r_{o2} \parallel R_o) = (1.2\text{m})(55.556\text{k} \parallel 6.584\text{M}) = 66.109 \text{ V/V} \quad [1]$$

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n [v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k'_n \cdot W}{2 \cdot L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p [v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k'_p \cdot W}{2 \cdot L}$$

; Small signal

$$g_m = 2\sqrt{K_n I_{DQ}}$$

$$r_o \cong \frac{1}{\lambda I_{DQ}}$$

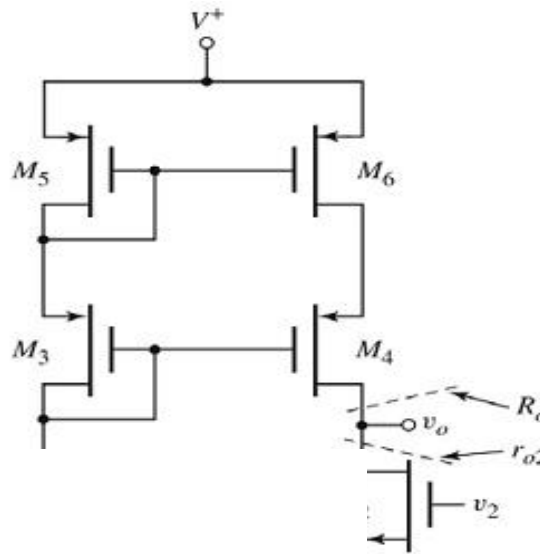
**Question:**

For a MOSFET differential amplifier with **cascode active load** shown in **Figure 1** the transistor parameters are  $g_m = 1.3 \text{ mA/V}$  for all transistors;  $K_n = 0.4 \text{ mA/V}^2$  and  $\lambda_n = 0.015 \text{ V}^{-1}$  for N-MOSFET transistors; and  $\lambda_p = 0.020 \text{ V}^{-1}$  for P-MOSFET transistors.

Find bias current ( $I_Q$ ) and calculate one-sided differential mode gain ( $A_d$ ) with output taken at  $v_o$ . Show clearly all formula used and calculations done as marks are given according to this.

[10 marks]

**Answer:**



; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n [v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k'_n}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p [v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k'_p}{2} \cdot \frac{W}{L}$$

; Small signal

$$g_m = 2\sqrt{K_n I_{DQ}}$$

$$r_o \cong \frac{1}{\lambda I_{DQ}}$$

$$\begin{aligned} g_m &= 2\sqrt{[K_{n2} \times I_{DQ}]} \\ &= 2\sqrt{[K_{n2} \times (I_Q/2)]} \\ I_Q &= [g_m / 2]^2 \times [2 / K_{n2}] \\ &= [g_m]^2 / [2 K_{n2}] \\ &= [1.3\text{m}]^2 / [2 \times 0.4\text{m}] = 2.113 \text{ mA} \end{aligned} \quad [1]$$

$$I_{DQ} = I_Q / 2 = 1.056 \text{ mA} \quad [1]$$

$$\begin{aligned} r_{o2} &= 1 / (\lambda_n I_{DQ}) \\ &= 1 / (0.015 \times 1.056\text{m}) = 63.116 \text{ k}\Omega \end{aligned} \quad [1]$$

$$\begin{aligned} r_{o4} &= r_{o6} = 1 / (\lambda_p I_{DQ}) \\ &= 1 / (0.020 \times 1.056\text{m}) = 47.337 \text{ k}\Omega \end{aligned} \quad [1]$$

$$\begin{aligned} R_o &= g_m r_{o4} r_{o6} \\ &= (1.3\text{m})(47.337\text{k})(47.337\text{k}) \\ &= 2.913 \text{ M}\Omega \end{aligned} \quad [1]$$

$$\begin{aligned} A_d &= g_m (r_{o2} \parallel R_o) \\ &= (1.3\text{m})(63.116\text{k} \parallel 2.913\text{M}) \\ &= 80.311 \text{ V/V} \end{aligned} \quad [1]$$

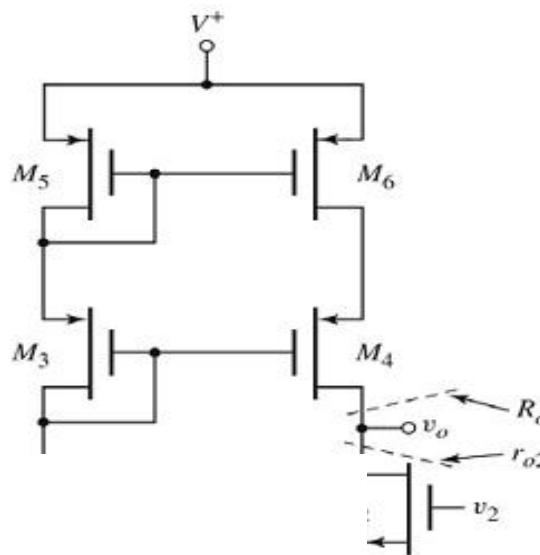
**Question:**

For a MOSFET differential amplifier with **cascode active load** shown in **Figure 1** the transistor parameters are  $g_m = 1.4 \text{ mA/V}$  for all transistors;  $K_n = 0.4 \text{ mA/V}^2$  and  $\lambda_n = 0.020 \text{ V}^{-1}$  for N-MOSFET transistors; and  $\lambda_p = 0.015 \text{ V}^{-1}$  for P-MOSFET transistors.

Find bias current ( $I_Q$ ) and calculate one-sided differential mode gain ( $A_d$ ) with output taken at  $v_o$ . Show clearly all formula used and calculations done as marks are given according to this.

[10 marks]

**Answer:**



$$\begin{aligned}
 g_m &= 2 \sqrt{[K_{n2} \times I_{DQ}]} \\
 &= 2 \sqrt{[K_{n2} \times (I_Q/2)]} \\
 I_Q &= [g_m / 2]^2 \times [2 / K_{n2}] & [1] \\
 &= [1.4\text{m}]^2 / [2 \times 0.4\text{m}] & [1] \\
 &= 2.450 \text{ mA} \\
 I_{DQ} &= I_Q / 2 = 1.225 \text{ mA} & [1] \\
 r_{o2} &= 1 / (\lambda_n I_{DQ}) & [1] \\
 &= 1 / (0.020 \times 1.225\text{m}) = 40.816 \text{ k}\Omega & [1] \\
 r_{o4} &= r_{o6} = 1 / (\lambda_p I_{DQ}) & [1] \\
 &= 1 / (0.015 \times 1.225\text{m}) = 54.422 \text{ k}\Omega & [1] \\
 R_o &= g_m r_{o4} r_{o6} & [1] \\
 &= (1.4\text{m})(54.422\text{k})(54.422\text{k}) & [1] \\
 &= 4.146 \text{ M}\Omega \\
 A_d &= g_m (r_{o2} \parallel R_o) & [1] \\
 &= (1.4\text{m})(40.816\text{k} \parallel 4.146\text{M}) & [1] \\
 &= 56.586 \text{ V/V} & [1]
 \end{aligned}$$

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n [v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k'_n}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p [v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k'_p}{2} \cdot \frac{W}{L}$$

; Small signal

$$g_m = 2\sqrt{K_n I_{DQ}}$$

$$r_o \cong \frac{1}{\lambda I_{DQ}}$$

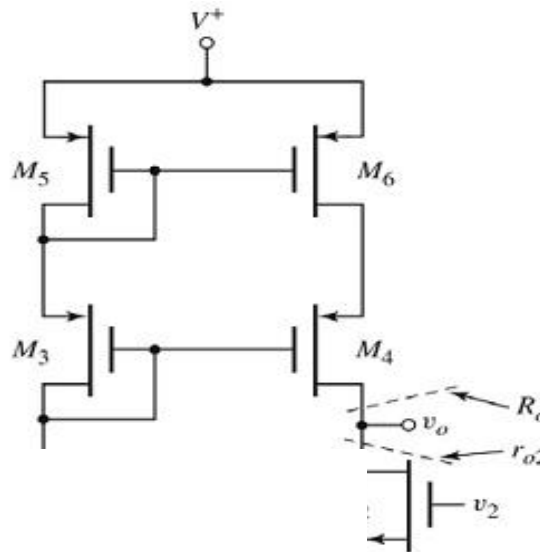
**Question:**

For a MOSFET differential amplifier with **cascode active load** shown in **Figure 1** the transistor parameters are  $g_m = 1.5 \text{ mA/V}$  for all transistors;  $K_n = 0.4 \text{ mA/V}^2$  and  $\lambda_n = 0.015 \text{ V}^{-1}$  for N-MOSFET transistors; and  $\lambda_p = 0.020 \text{ V}^{-1}$  for P-MOSFET transistors.

**Find** bias current ( $I_Q$ ) and **calculate** one-sided differential mode gain ( $A_d$ ) with output taken at  $v_o$ . **Show clearly** all formula used and calculations done as marks are given according to this.

[10 marks]

**Answer:**



; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n [v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k'_n}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p [v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k'_p}{2} \cdot \frac{W}{L}$$

; Small signal

$$g_m = 2\sqrt{K_n I_{DQ}}$$

$$r_o \cong \frac{1}{\lambda I_{DQ}}$$

$$\begin{aligned} g_m &= 2\sqrt{[K_{n2} \times I_{DQ}]} \\ &= 2\sqrt{[K_{n2} \times (I_Q/2)]} \\ I_Q &= [g_m / 2]^2 \times [2 / K_{n2}] \\ &= [1.5\text{m}]^2 / [2 \times 0.4\text{m}] = 2.813 \text{ mA} \end{aligned} \quad [1]$$

$$I_{DQ} = I_Q / 2 = 1.406 \text{ mA} \quad [1]$$

$$\begin{aligned} r_{o2} &= 1 / (\lambda_n I_{DQ}) \\ &= 1 / (0.015 \times 1.406\text{m}) = 47.407 \text{ k}\Omega \end{aligned} \quad [1]$$

$$\begin{aligned} r_{o4} &= r_{o6} = 1 / (\lambda_p I_{DQ}) \\ &= 1 / (0.020 \times 1.406\text{m}) = 35.556 \text{ k}\Omega \end{aligned} \quad [1]$$

$$\begin{aligned} R_o &= g_m r_{o4} r_{o6} \\ &= (1.5\text{m})(35.556\text{k})(35.556\text{k}) \\ &= 1.896 \text{ M}\Omega \end{aligned} \quad [1]$$

$$\begin{aligned} A_d &= g_m (r_{o2} \parallel R_o) \\ &= (1.5\text{m})(47.407\text{k} \parallel 1.896\text{M}) \\ &= 69.377 \text{ V/V} \end{aligned} \quad [1]$$